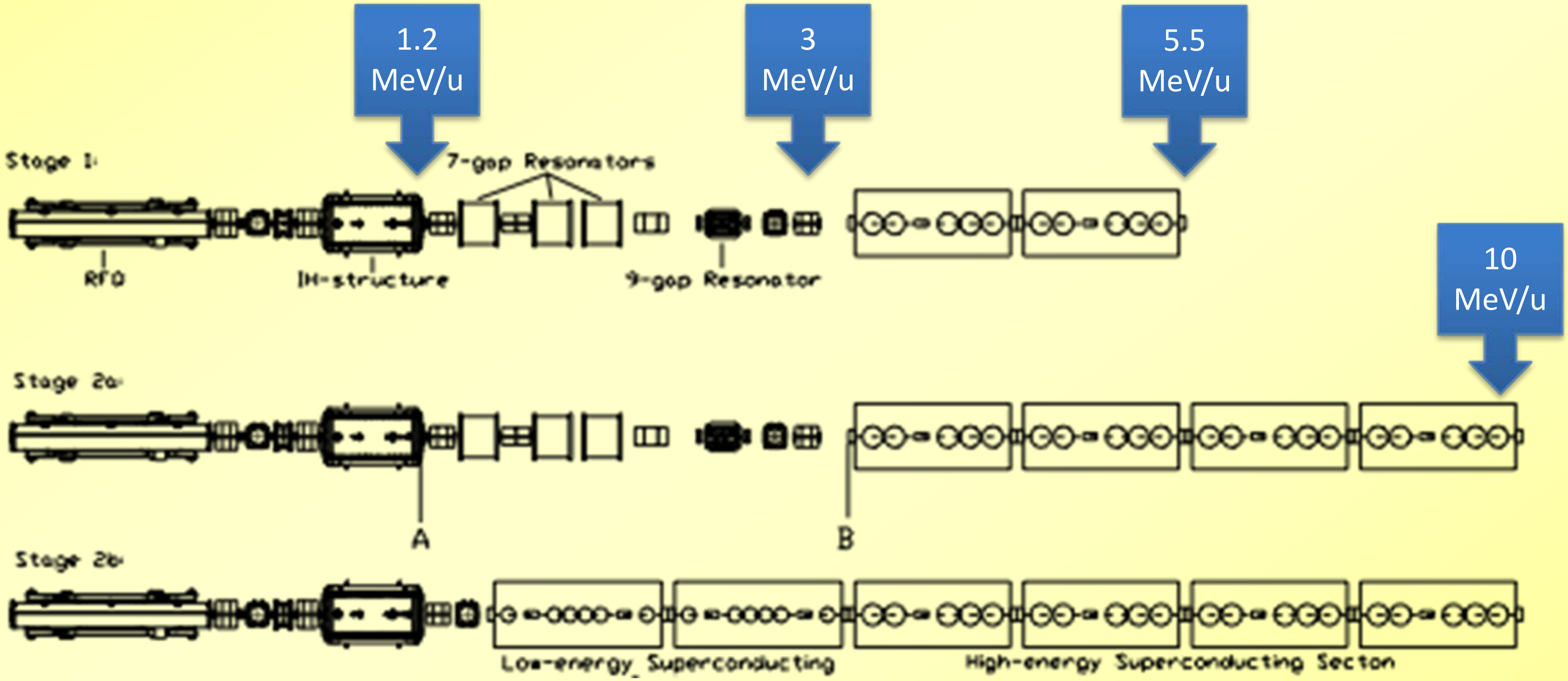
HIE-ISOLDE SC-RF Cavities

Sergio Calatroni

HIE linac staged installation

3 stages installation



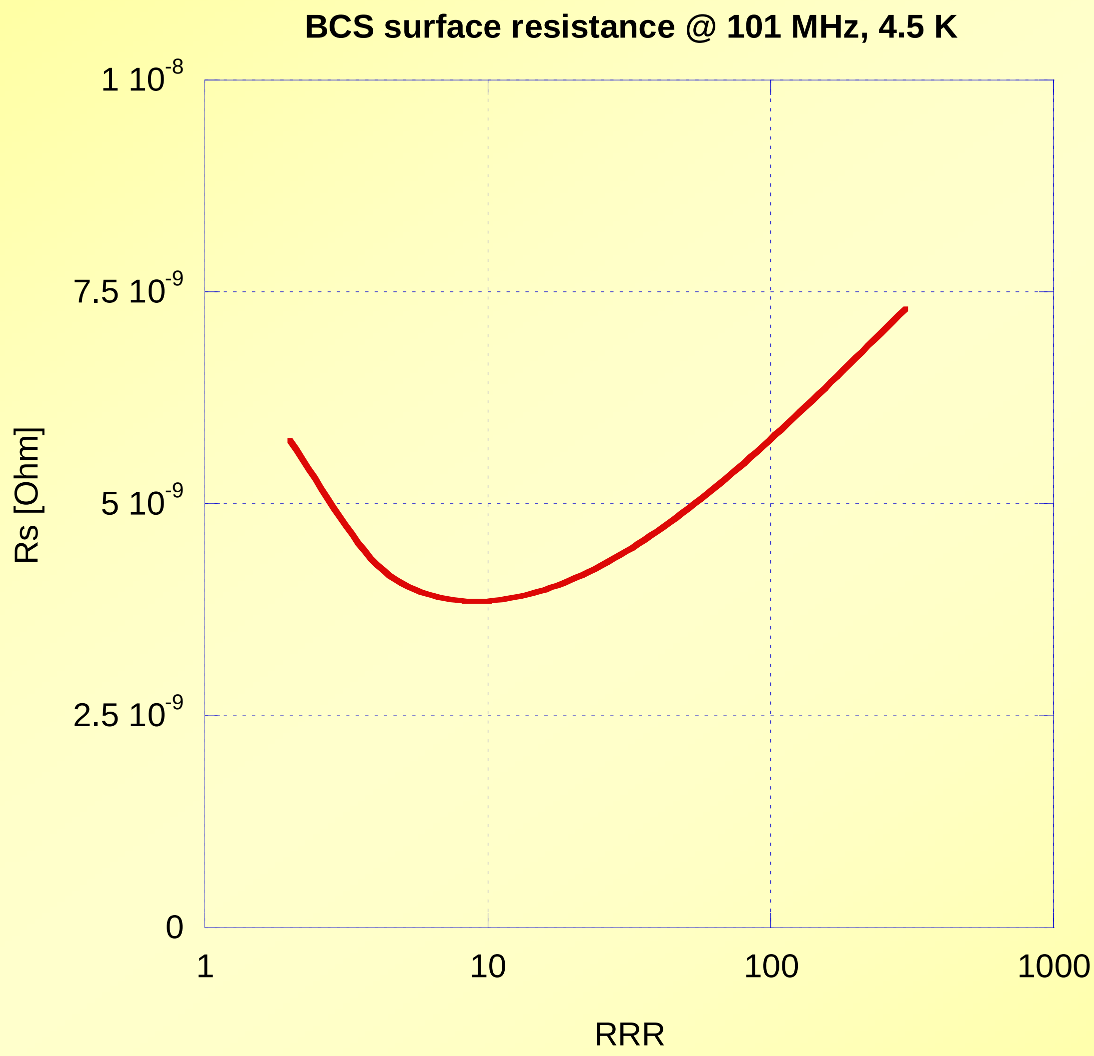
From: M. Pasini

Why Nb/Cu cavities?

- Mechanical stability (reduction of microphonics and sensitivity to He bath pressure)
- Simpler cryostat: no magnetic shielding, conduction cooling
- CERN experience (LEP, LHC, R&D)
  - Largest experience of niobium sputtering for cavities
  - Extensive experience of copper surface treatments
- Available experience from INFN-LNL
  - Choice of biased diode sputtering as baseline

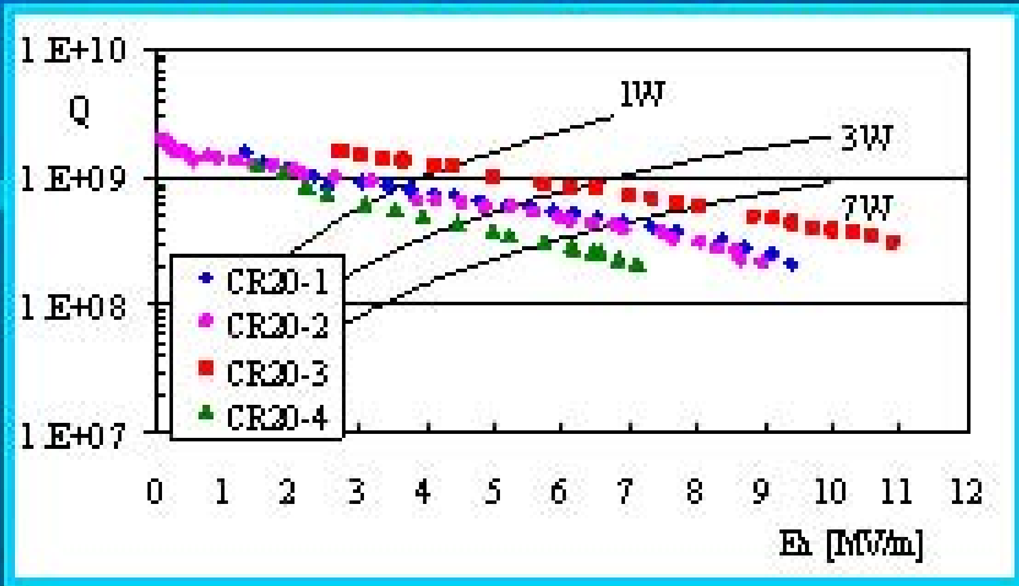
- EuCARD WP10.4.3: development of sputter technology (magnetron sputtering, Hipims) for QWR, aimed at HIE-ISOLDE

BCS surface resistance



Performance will be dominated by R_{res} which is expected to be acceptable for our target parameters. Our goal < 75 nOhm @ nominal field

ALPI high β QWRs



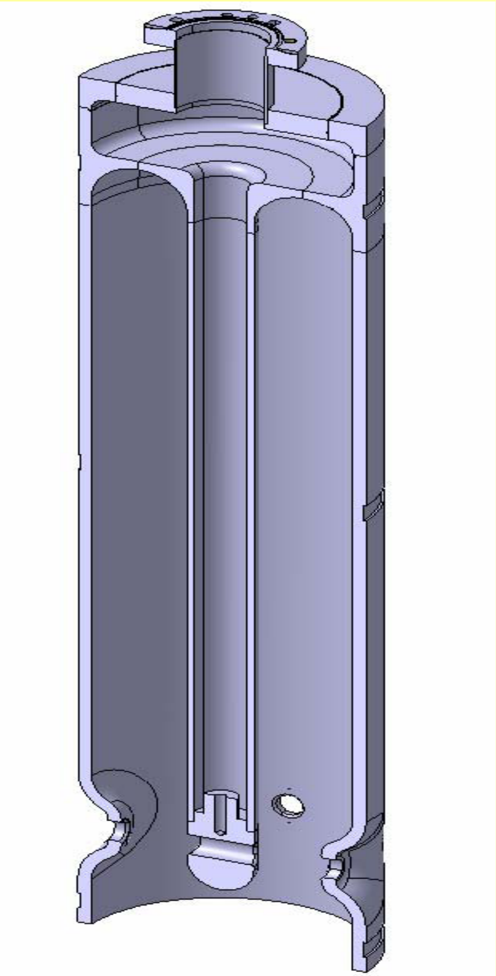
β=0.13, 160 MHz

- ❑ Drilled by a billet of OFHC Cu, 99.95% certificate grade
- ❑ No brazed joints, beam ports jointed by indium gaskets
- ❑ Rounded shorting plate
- ❑ Capacitive coupler

- ❑ CR20 resonators are in ALPI since 1988
- ❑ The average operational accelerating field is 6 MV/m; the cavity CR20-3 is routinely amplitude and phase locked at 7.3 MV/m
- ❑ CR19, housing cavities similar in shape, but having a brazed substrate, was installed ALPI in 2001
- ❑ No other cryostats are available for installation of further cavities

L.N.L. Thin film _ Workshp, Porcellato 9 Oct 2006

Low-β and high- β cavities



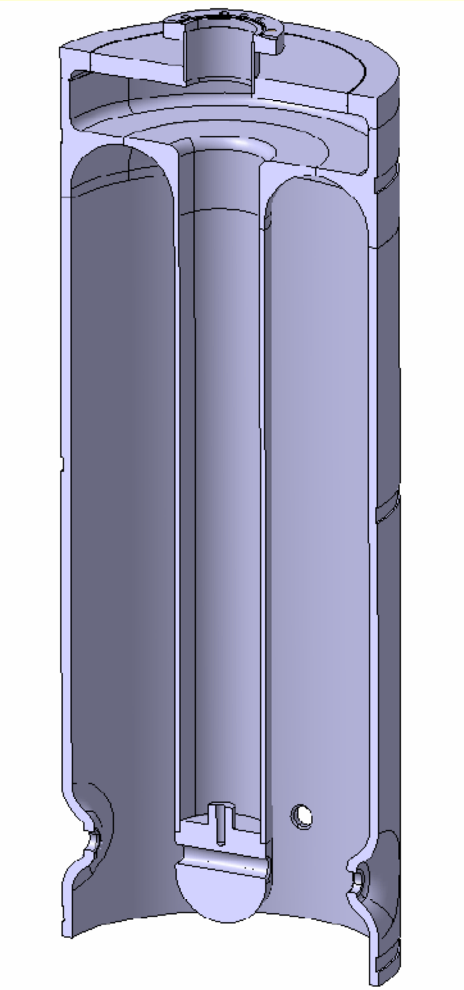
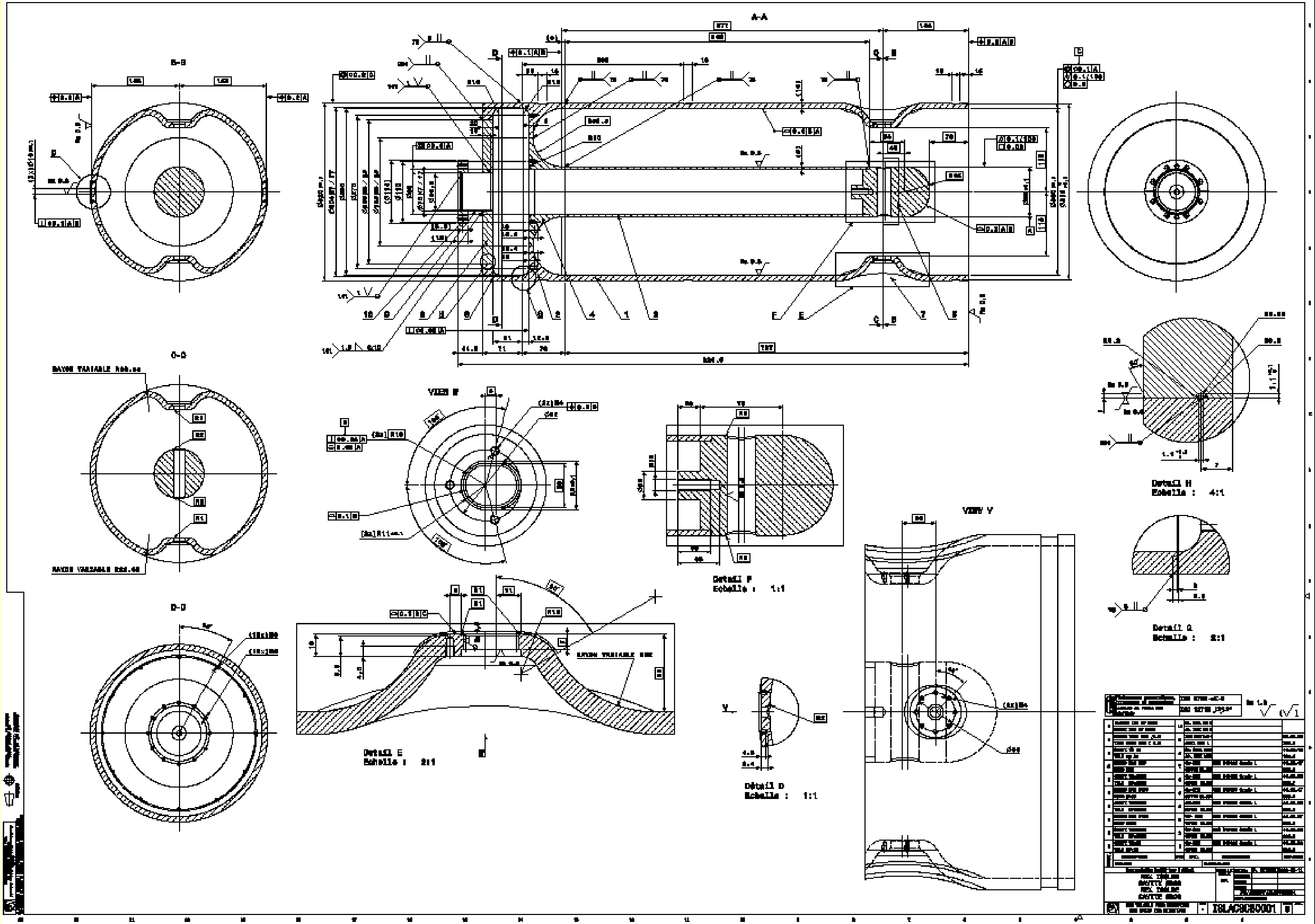


Table 1: Cavity design parameters

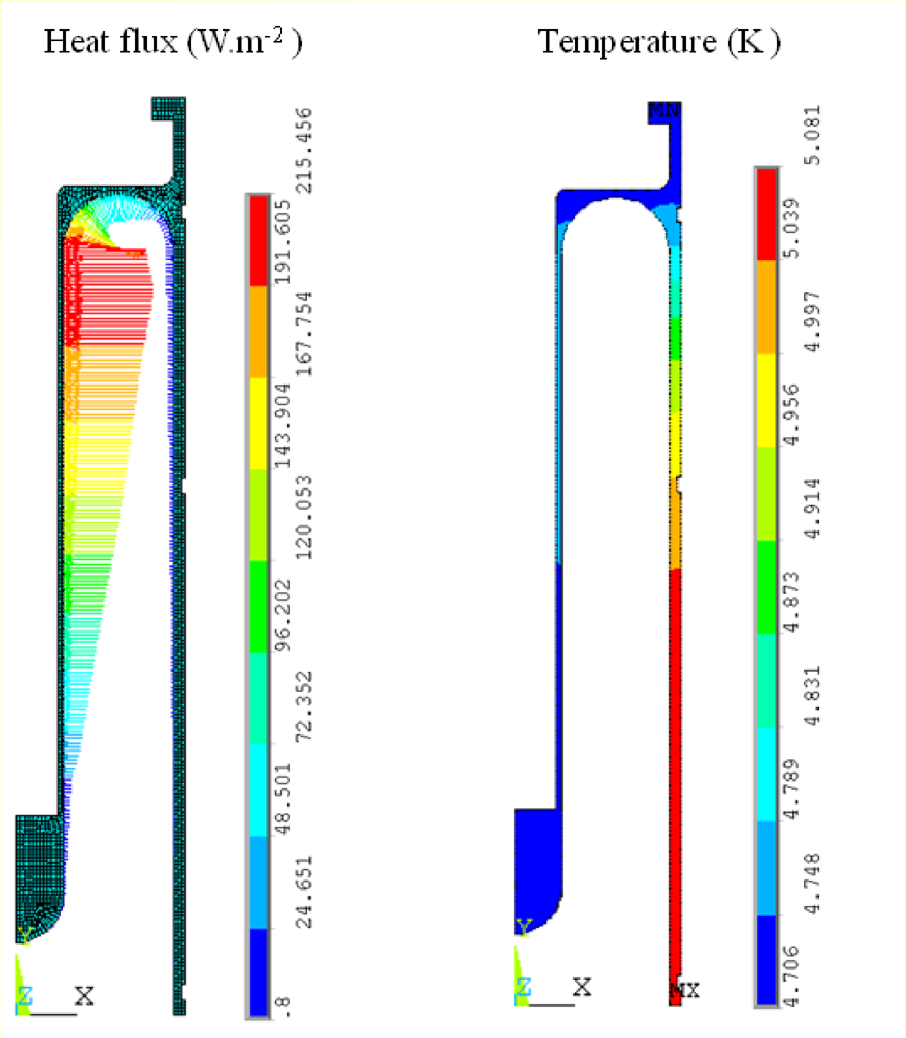
Cavity	**Low** β	**high** β
No. of Cells	2	2
f (MHz)	101.28	101.28
β_0 (%)	6.3	10.3
Design gradient E_{acc}(MV/m)	6	6
Active length (mm)	195	300
Inner conductor diameter (mm)	50	90
Mechanical length (mm)	215	320
Gap length (mm)	50	85
Beam aperture diameter (mm)	20	20
$U/E_{acc}{}^2$ (mJ/(MV/m)^2	73	207
E_{pk}/E_{acc}	5.4	5.6
H_{pk}/E_{acc} (Oe/MV/m)	80	100.7
R_{sh}/Q (Ω)	564	548
$\Gamma = R_s \cdot Q_0$	23	30.6
Q_0 for 6MV/m at 7W	$3.2 \cdot 10^8$	$5 \cdot 10^8$
TTF max	0.85	0.9
No. of cavities	12	20

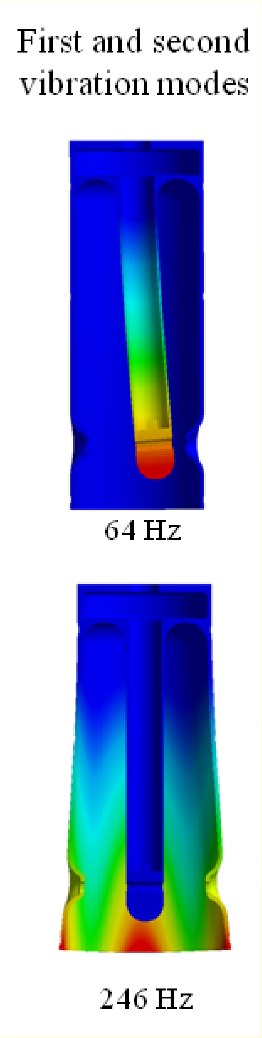

A-A
B-B
C-C
D-D
VIEW V
Detail H
Echelle : 4:1
Detail G
Echelle : 2:1
Detail F
Echelle : 1:1
Detail E
Echelle : 2:1
Detail D
Echelle : 1:1

Mechanical design criteria

- Avoid any brazing or annealing:
  - Negative experience from LNL for coating performance
  - Loss of mechanical properties
- Cu-OFE C10100 cold worked (rolled sheets, forged billets).
- Choice of manufacturing 100% at CERN workshop, thus using only available techniques:
  - Long distance EB welding possible
  - Inner EB welding not possible
  - Deep drawing preferred over 3D machining for beam ports.

FEM analyses



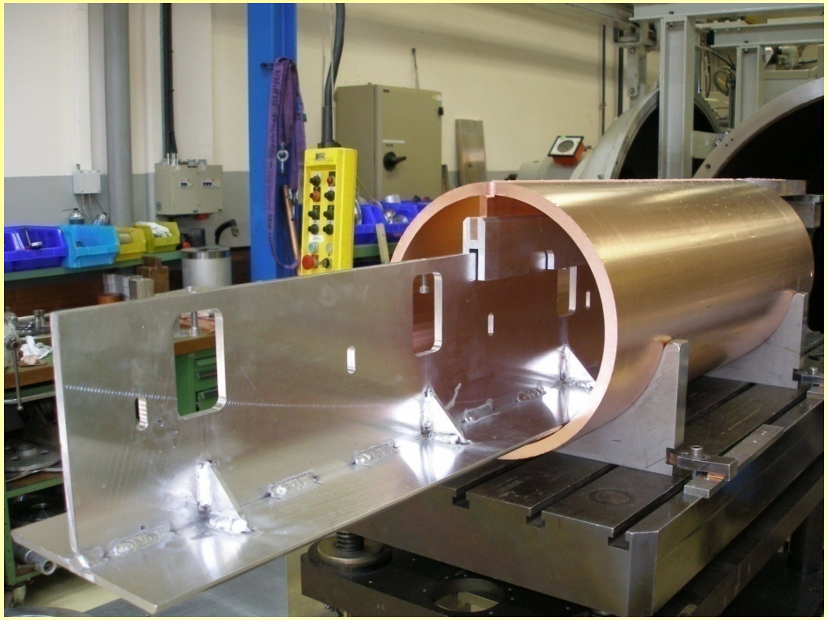


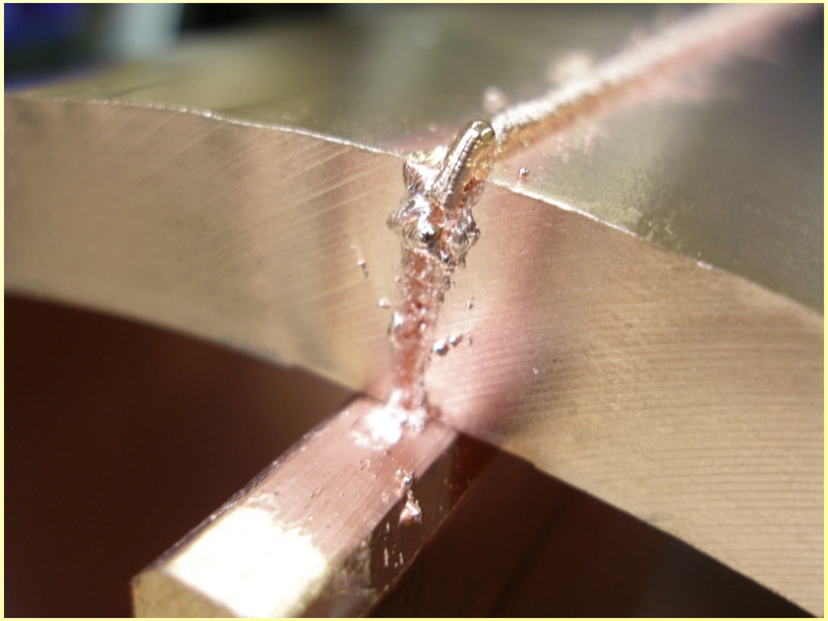
Heat flux input and resulting temperature distribution in the cavity, considering the thermal conductivity of copper RRR=100 and pool boiling cooling in convection and nucleate boiling regimes.

First and second vibration mode shapes and corresponding frequencies.

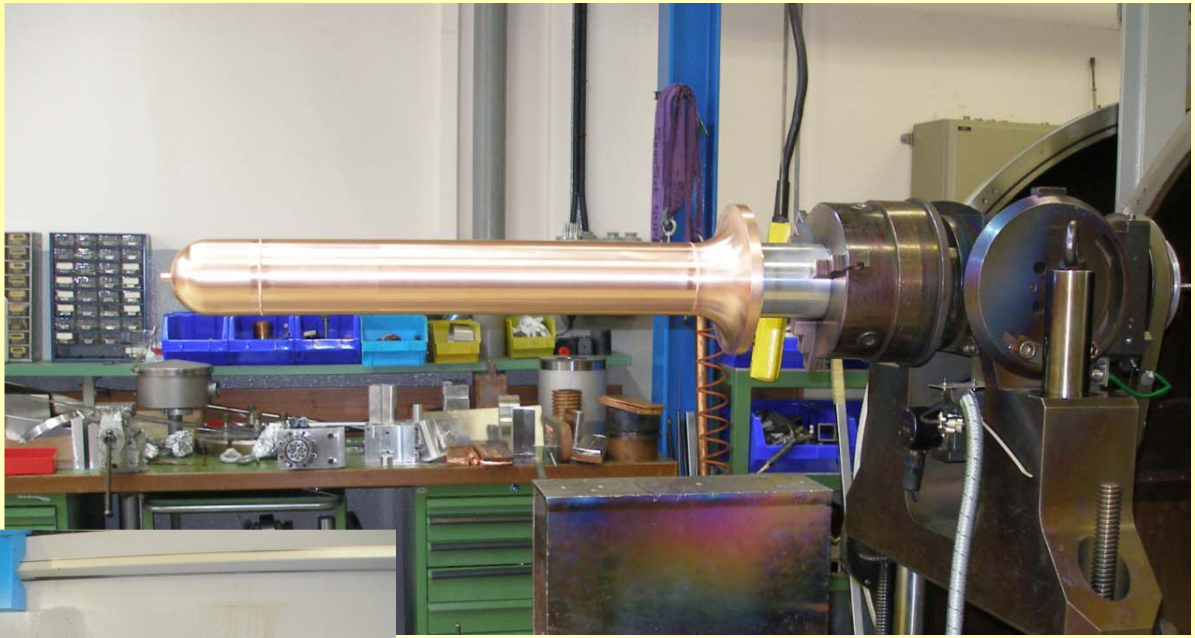
Inner and outer cylinders

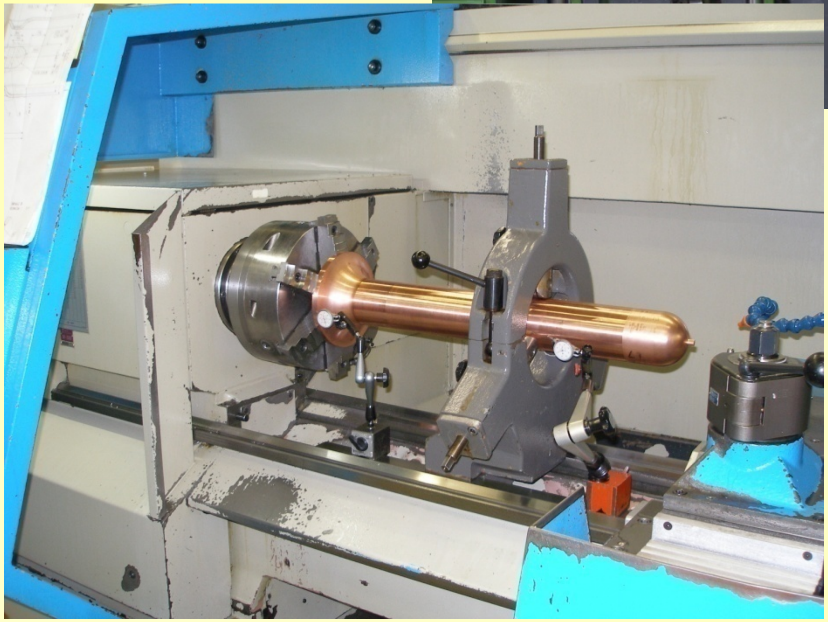
Outer cylinder

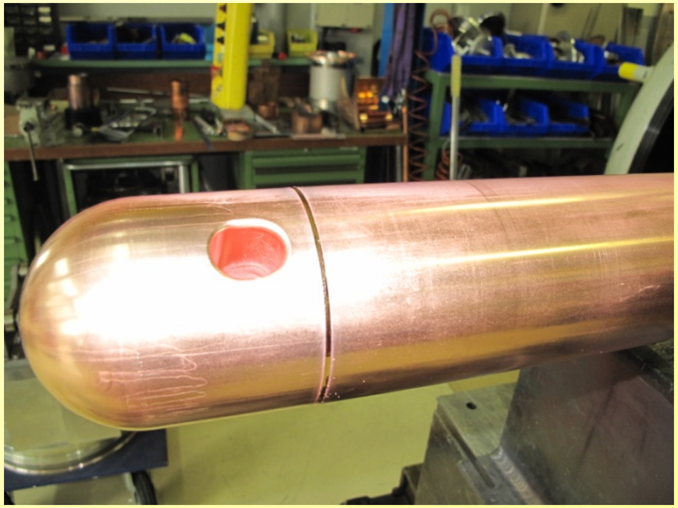




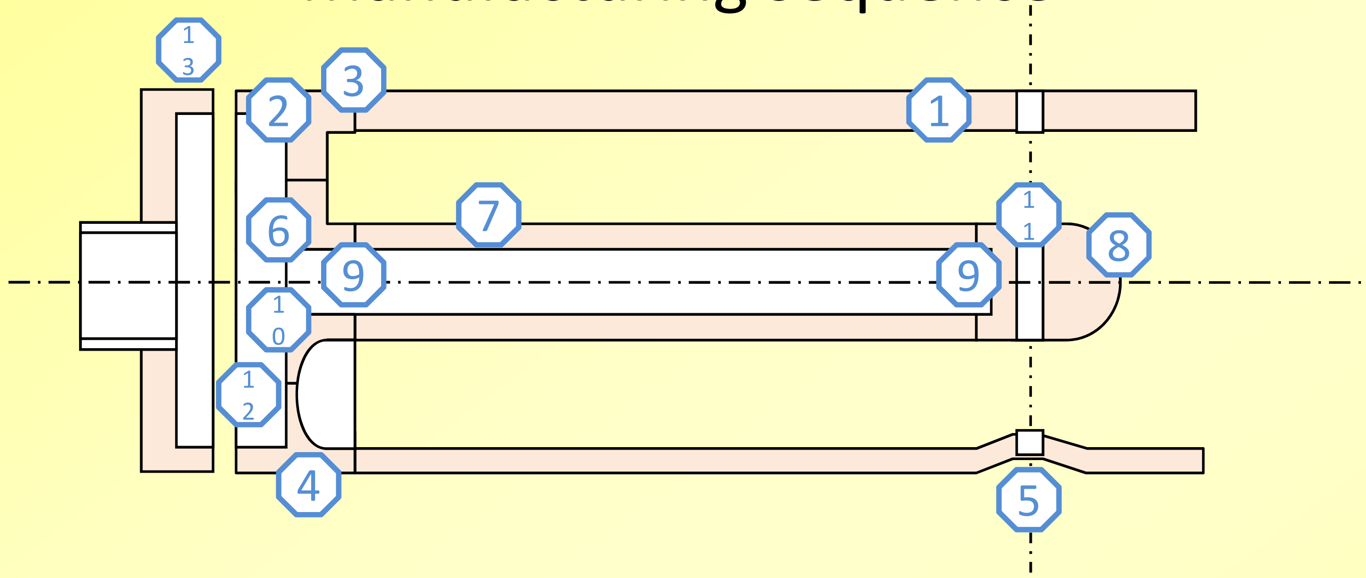
Inner cylinder







Manufacturing sequence



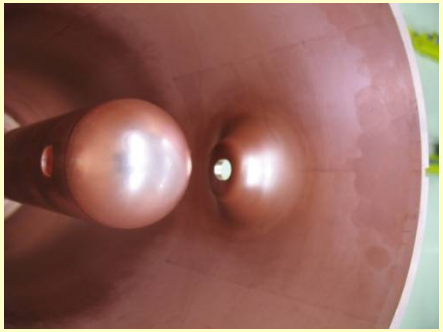
1. Rolling of half tubes, longitudinal welding, rough machining
2. Machining of end piece
3. E-beam welding
4. Fine machining of inner surface
5. “Bossage” and machining of beam ports
6. Manufacturing of baseplate of inner conductor
7. Manufacturing of central tube
8. Manufacturing of head
9. E-beam welding of the 3 parts of inner conductor
10. Fine machining of inner conductor
11. Drilling of beam line
12. Final long-distance e-beam welding
13. E-beam welding of top flange ensemble

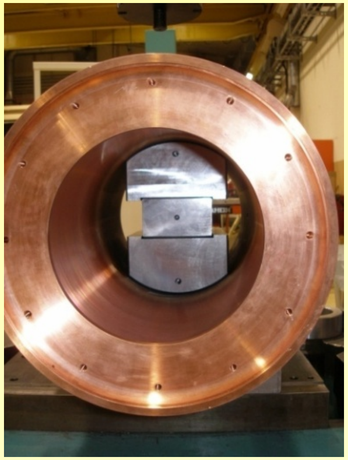
Welding test: 1000 mm distance e-beam

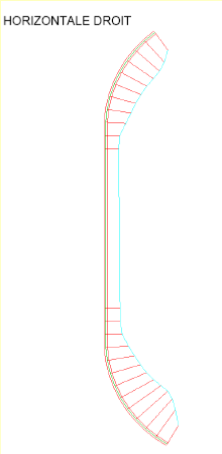
Roughness measured after welding and SUBU chemical polishing, 20 µm removed

Achieved Ra better than 0.8 µm, target value based on LEP/LHC/1.5 GHz CERN experience

Beam ports







Obtained shape accuracy
better than 0.1 mm

Design of bias sputter coating system

Vacuum tank

Cavity

Thermal shield

Cooling

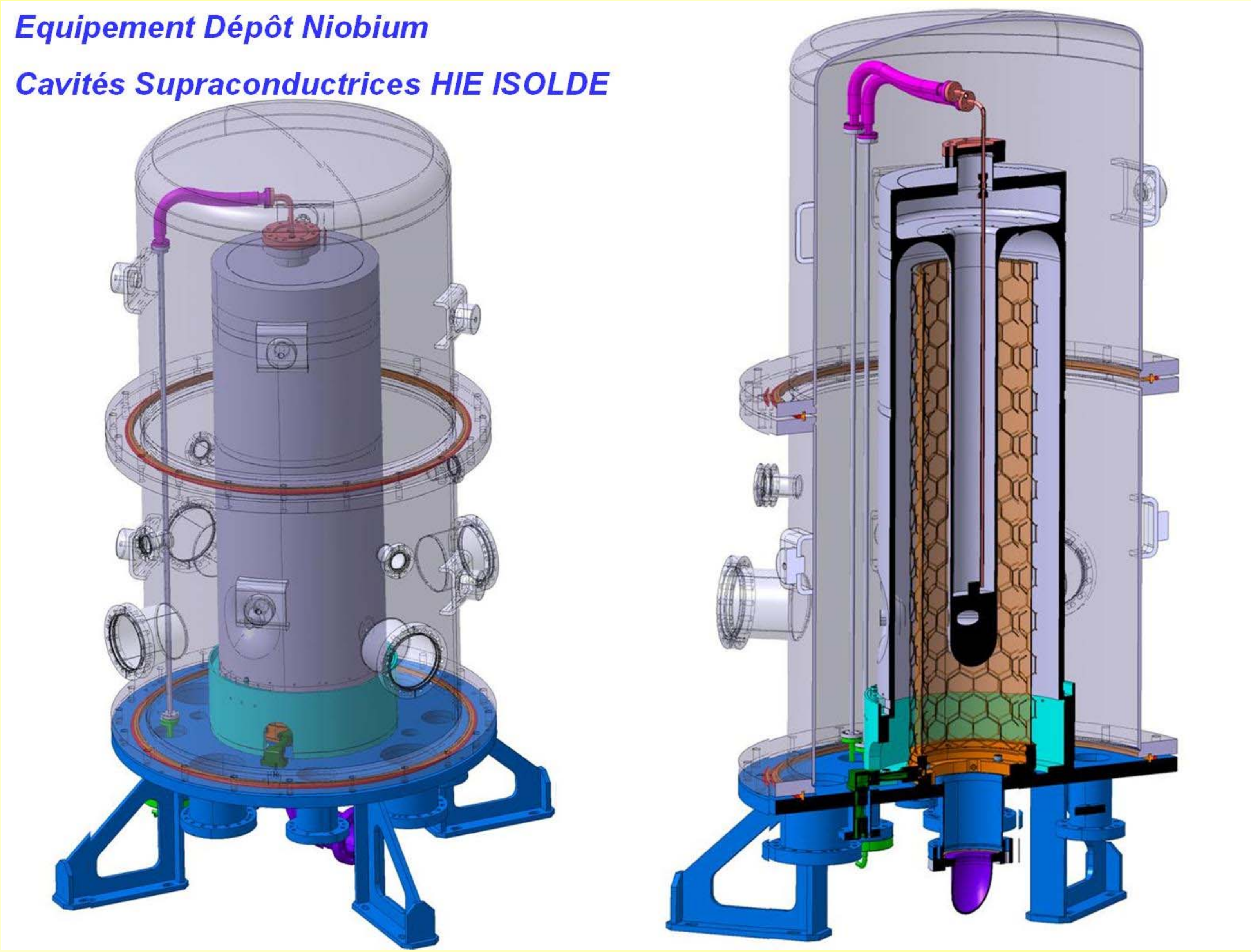
Sputtering cathode

Cooling feedthrough

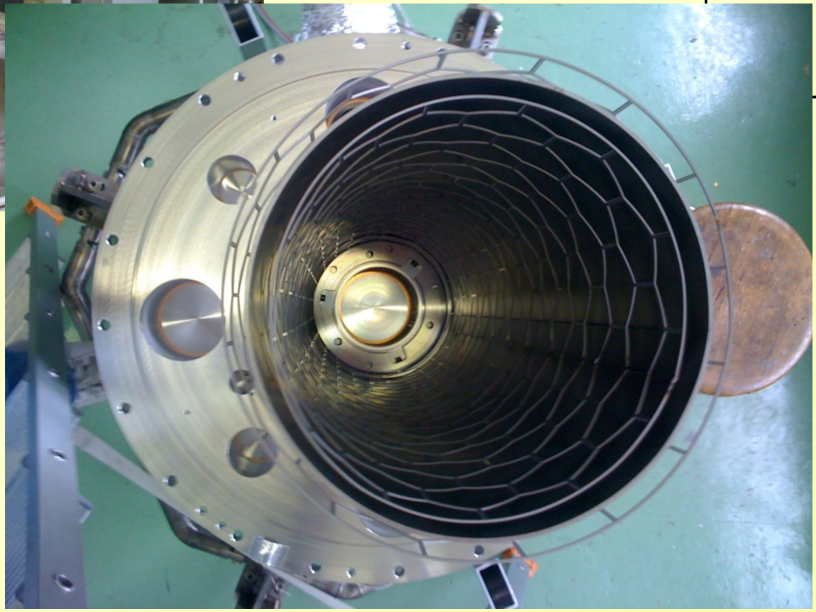
HV feedthrough

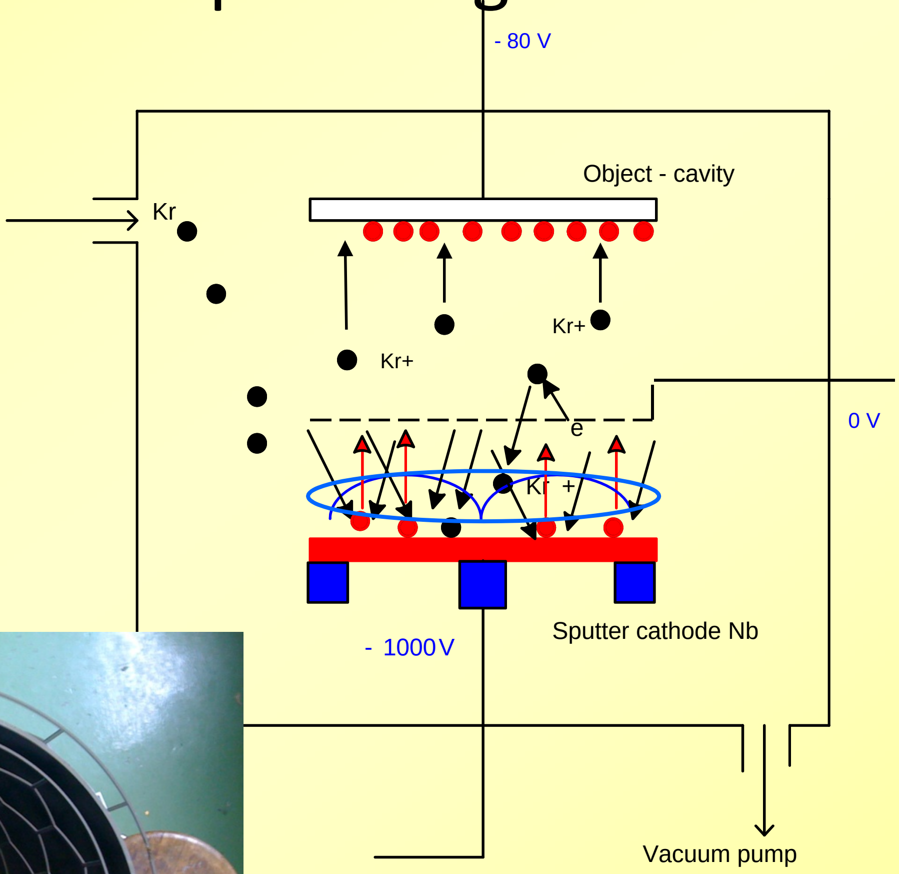
Pump connection

Coating assembly: cathodes and cavity cooling



Details of diode bias sputtering

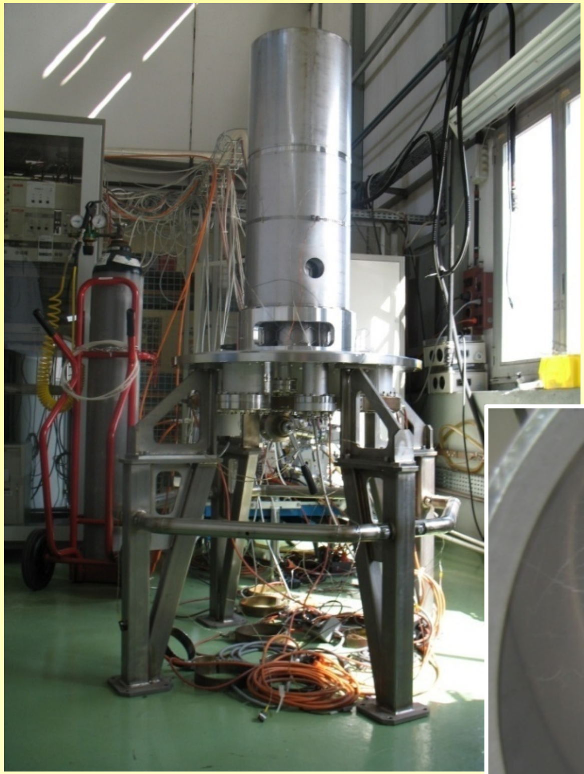


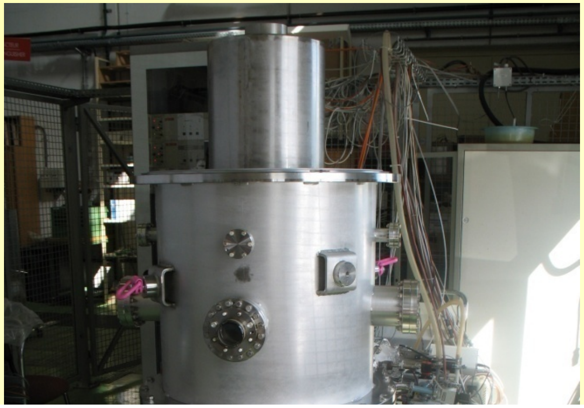


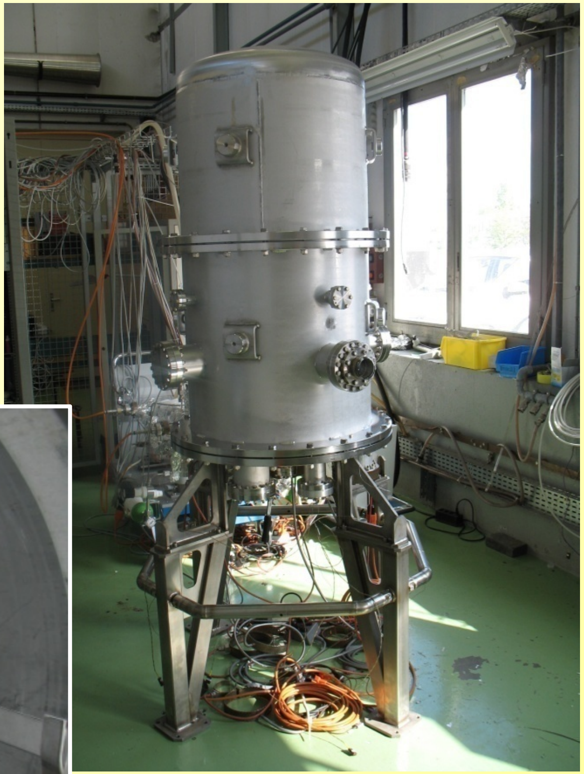
Target thickness: 1 µm (20x δ)

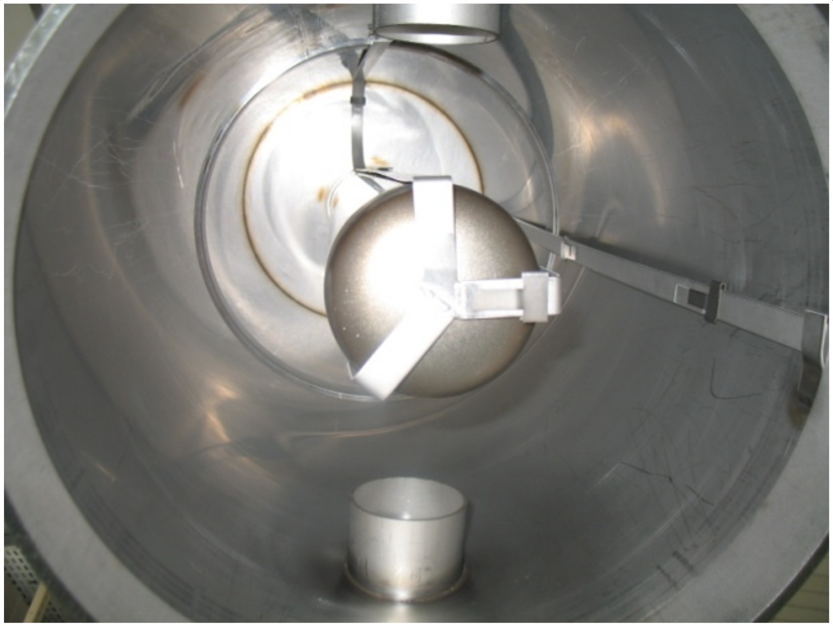
Cavity cooled during coating

Tests on samples



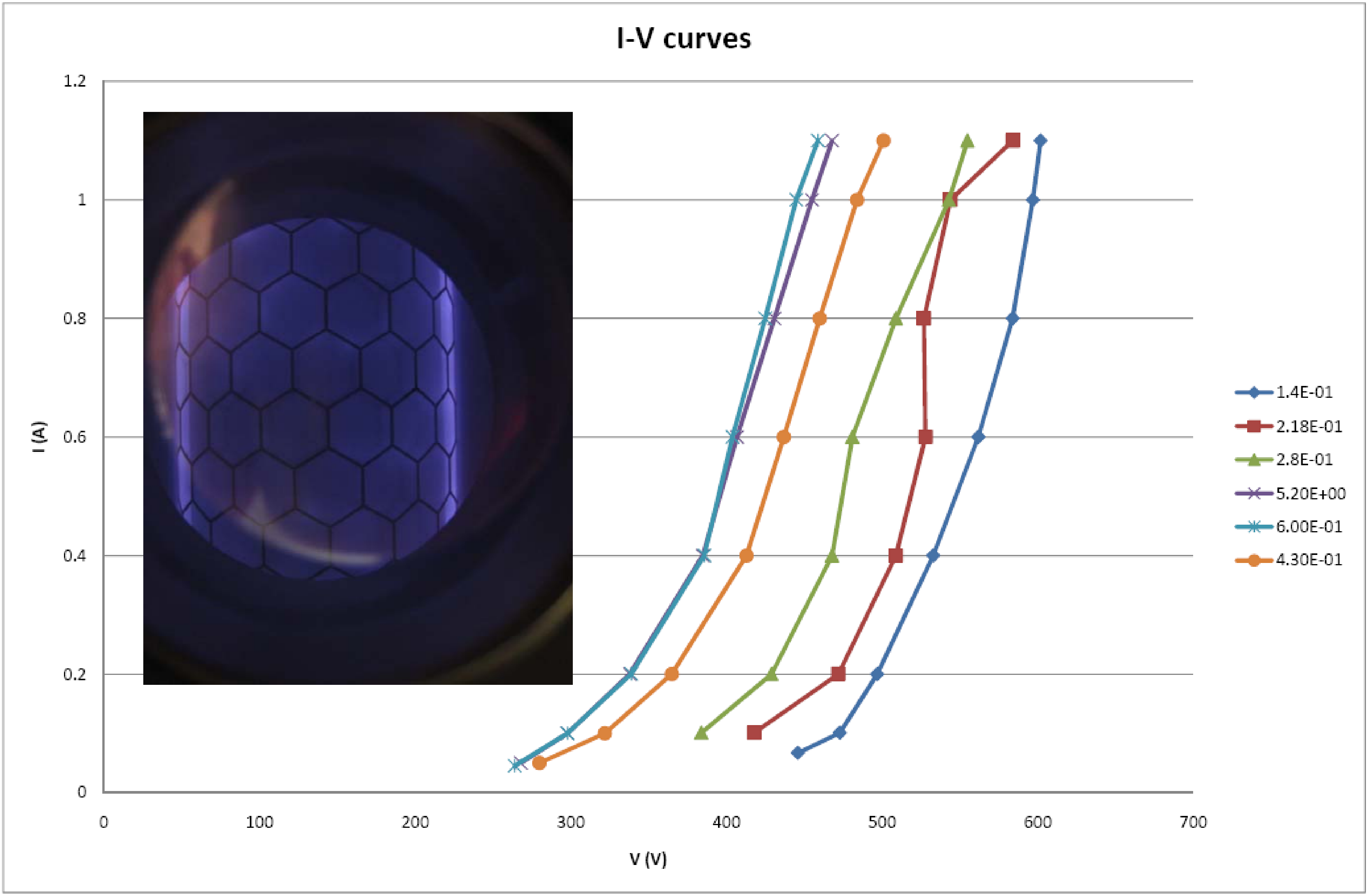






Quartz samples for thickness calibration, RRR, Tc

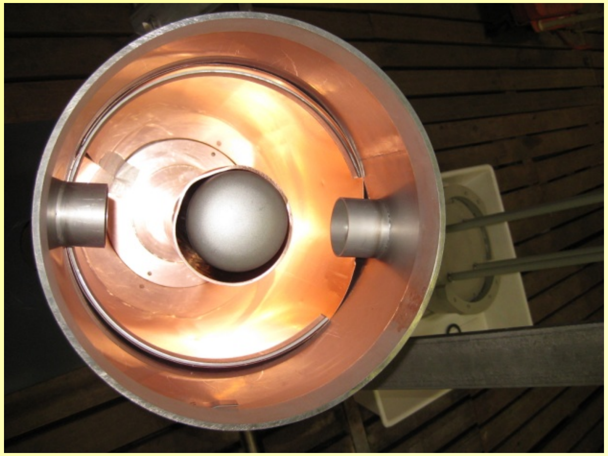
First plasma (Kr as sputter gas)



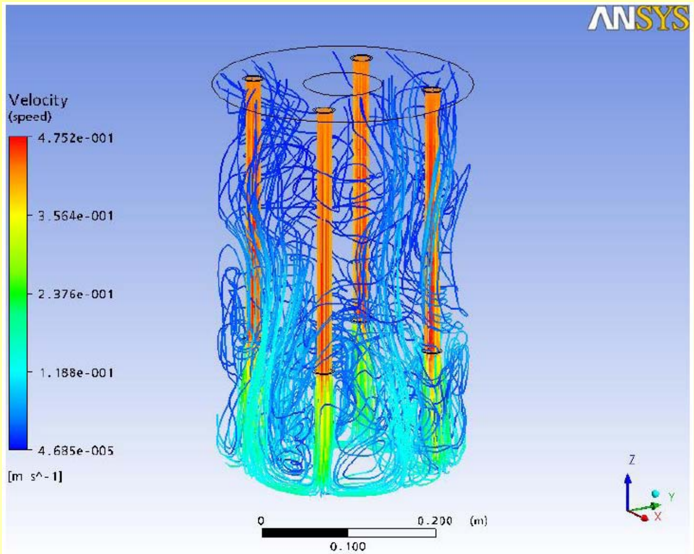
Foreseen coating procedure and quality controls

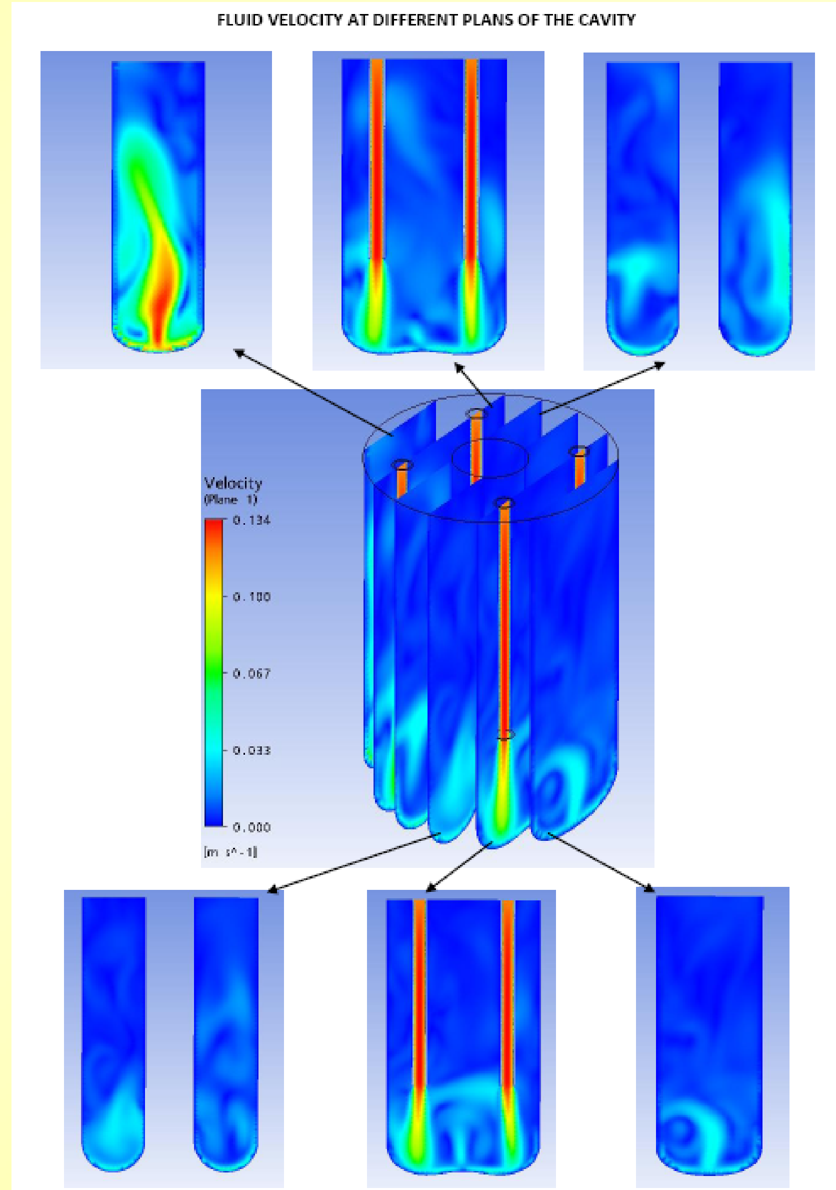
- Cavity manufacturing
  - Metrology checks, US and X-ray of weldings, roughness guaranteed by respect of manufacturing procedure (checked on samples)
- Surface treatment: SUBU 20 µm
  - Check by weigh loss and visual inspection
- Coating:
  - Quality checked by RRR and Tc on quartz samples
  - Control and reproduction of sputtering parameters: Kr pressure, sputter V-I, bias voltage, cavity temperature.
- (Water rinsing: resistivity, particle count and TOC of output water)

Surface treatment



CFD studies of chemical polishing bath

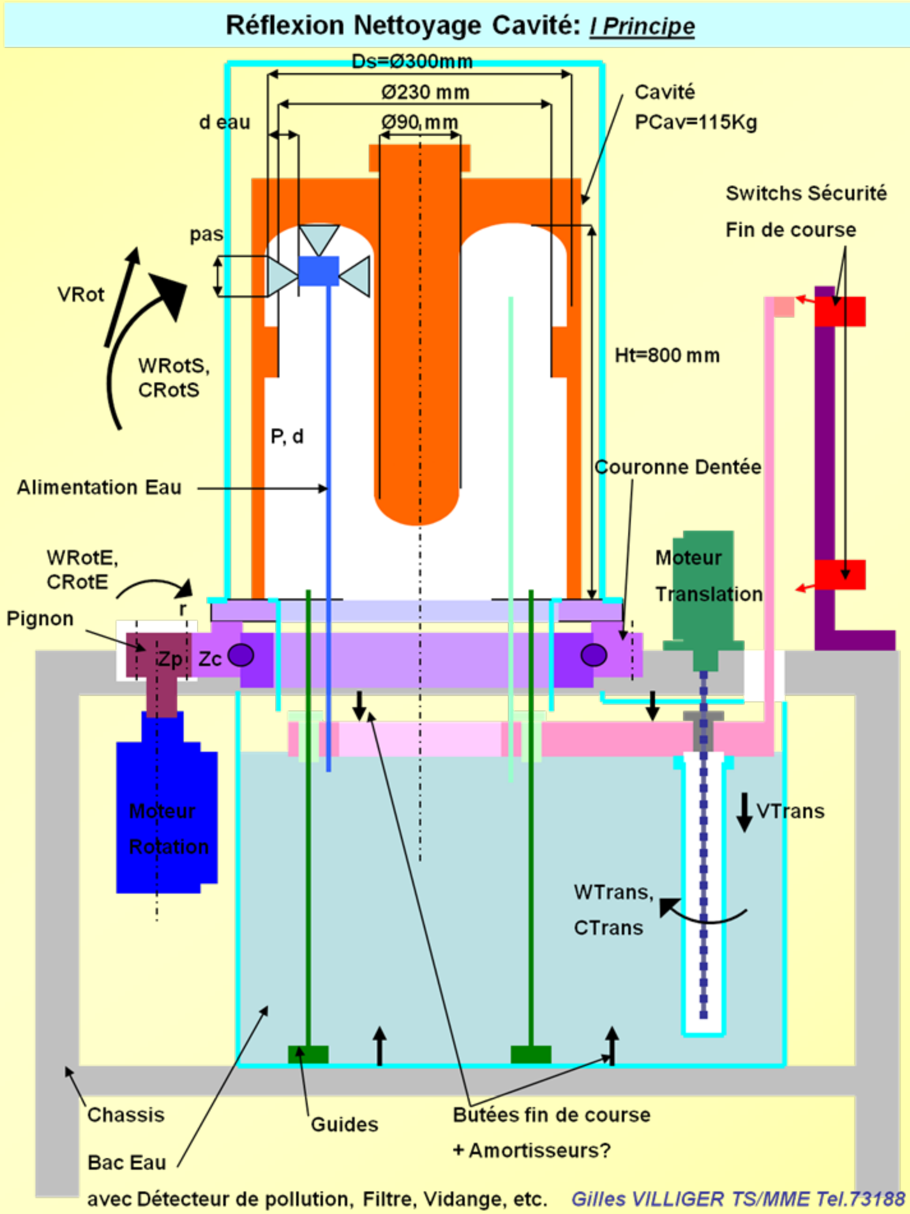




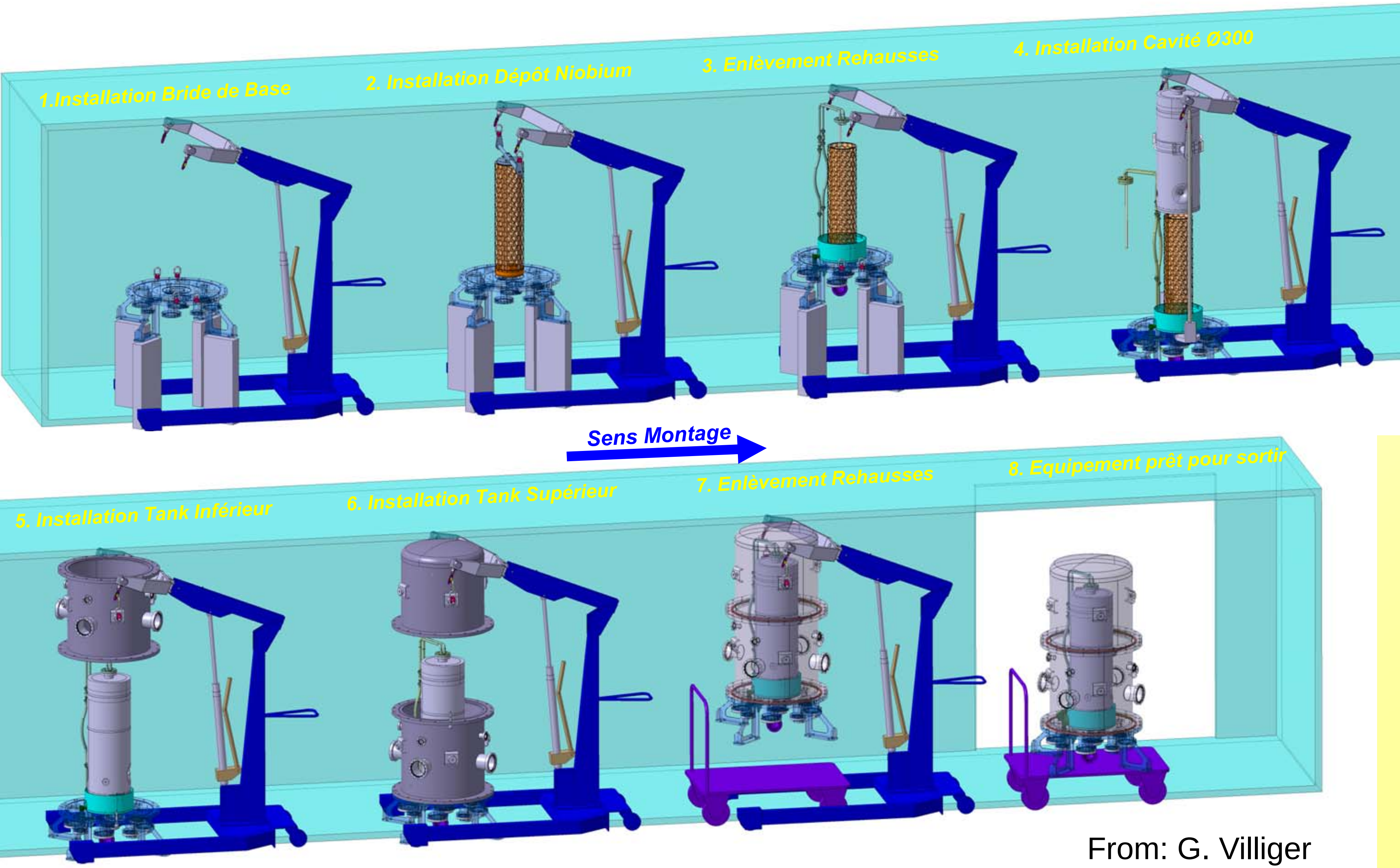
The velocity of the fluid close the bottom wall of the cavity is quite uniformly distributed.
The values obtained are comprised between 0.04 m/s and 0.06 m/s.

SUBU: Sulfamic acid (H_3NO_3S) 5 g/L, H_2O_2 5% vol, n-butanol $C_4H_{10}O$ 5% vol, di-ammonium citrate ($C_6H_{14}N_2O_2$) 1 g/L.
Chemical polishing is carried out at 72 °C and is preceded and followed by washing with H_3NO_3S.

Study of rinsing system (after CP/ after coating)

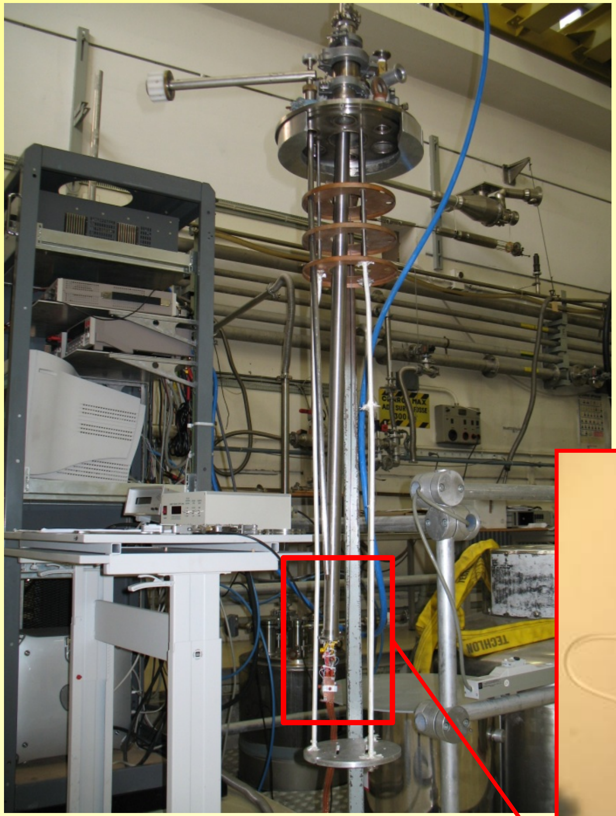


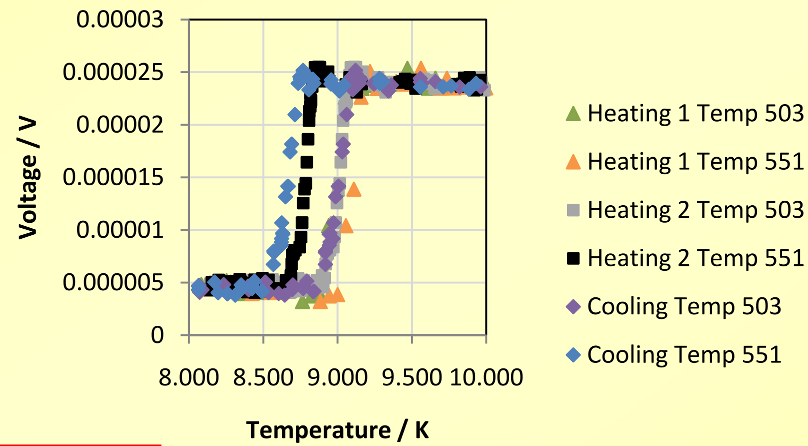
Study of clean room assembly

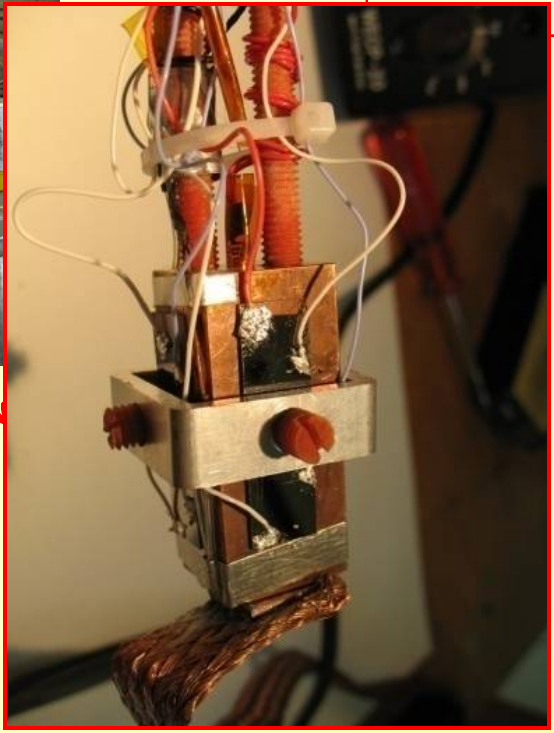


From: G. Villiger

RRR measurements

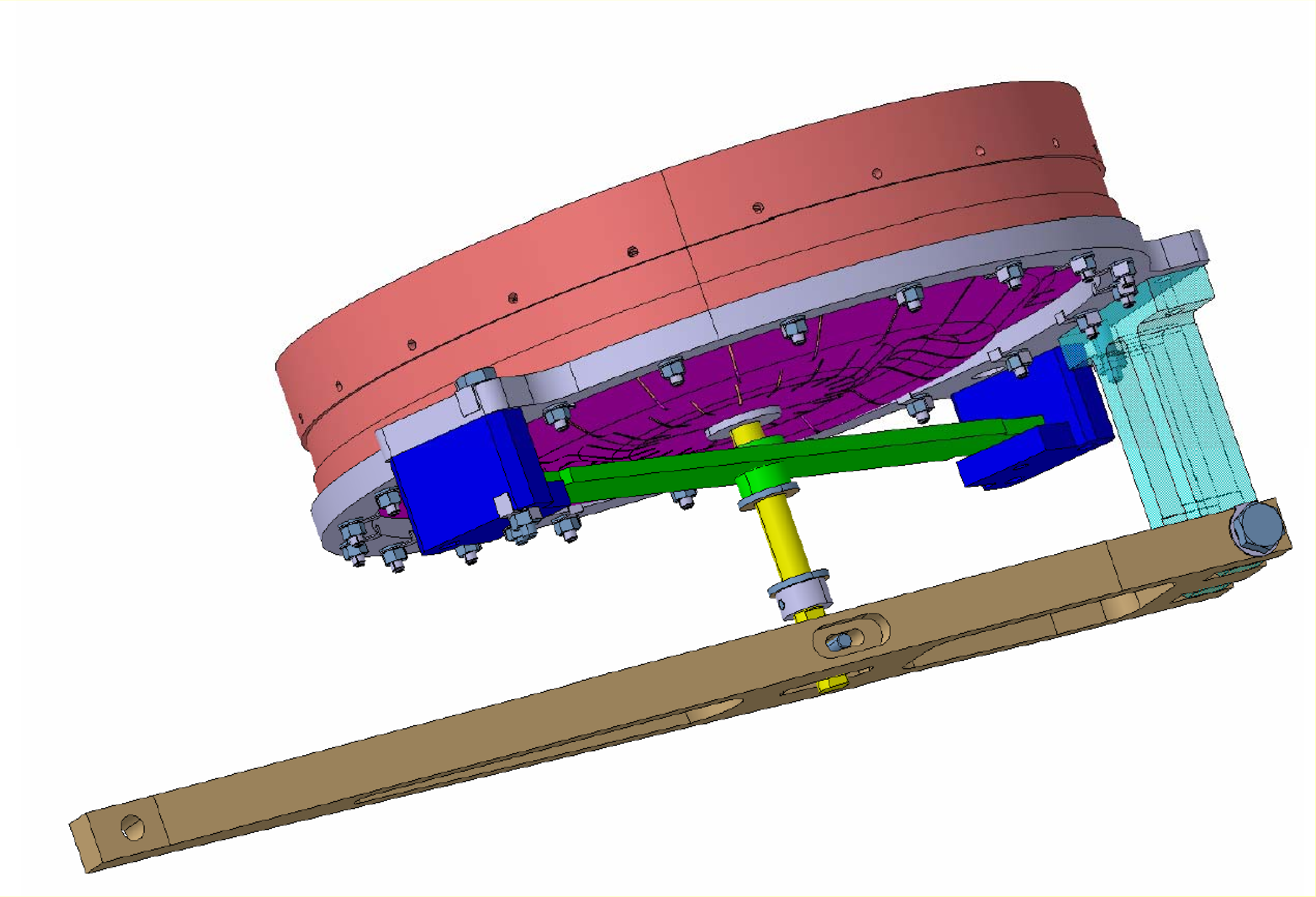




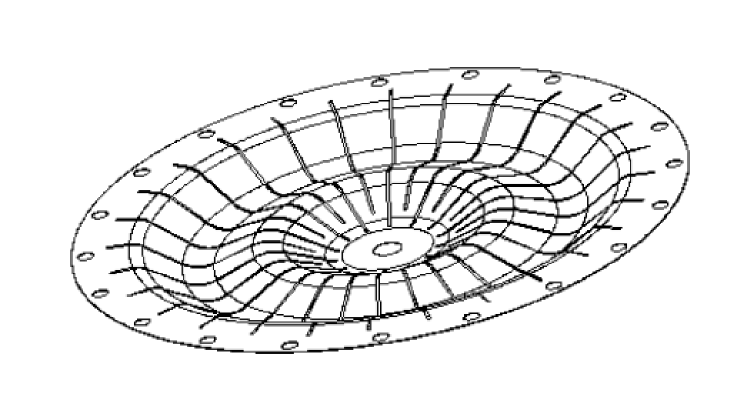


System tested for preliminary Nb coating run of RF tuning plate

Study of RF tuning plate (in construction)



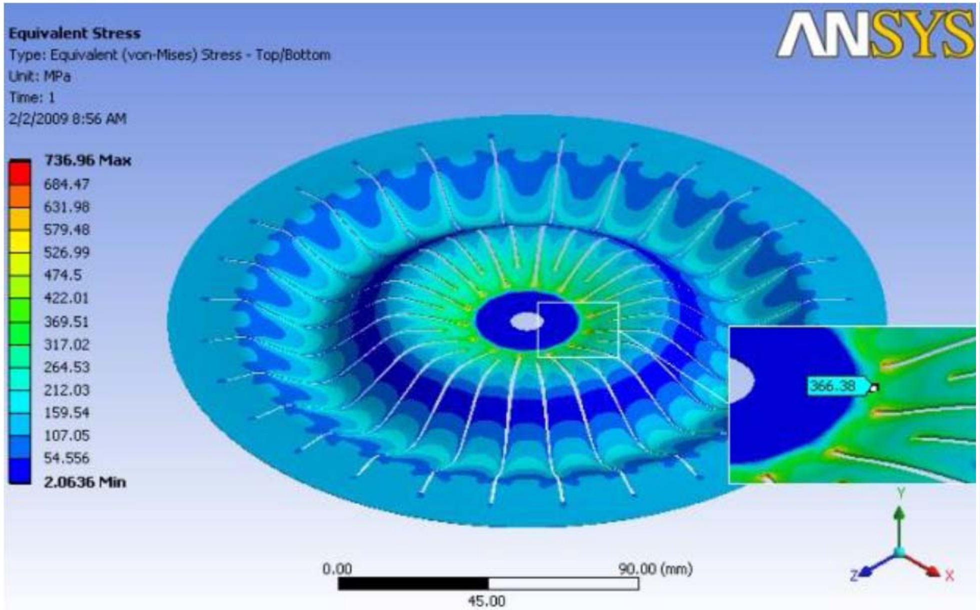
FEM analyses



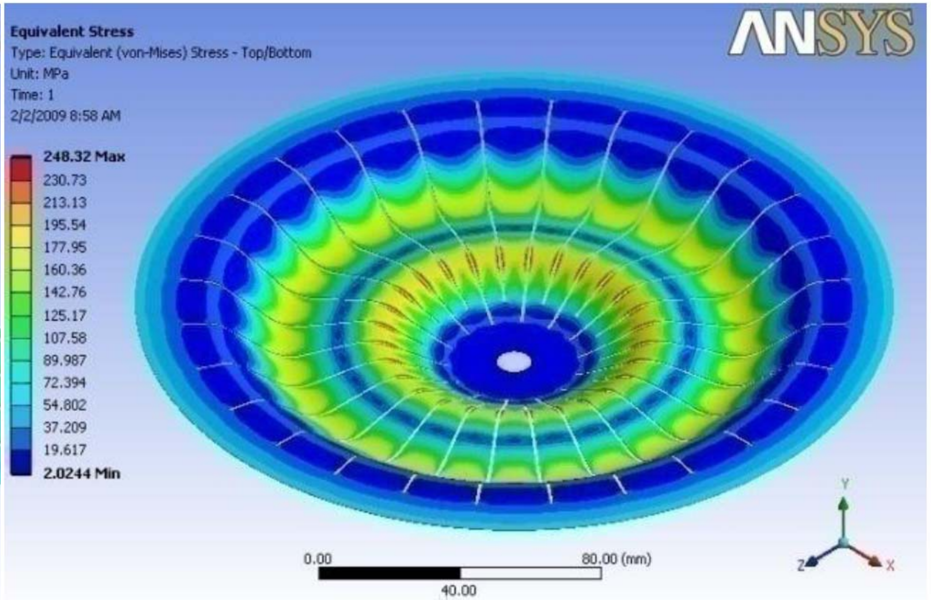
Displacement: +15 mm (up)
-5 mm (down)

(Apparent concentration of stresses due to probable numerical errors. Plastification would anyhow spread the stress around)

Material	Young Modulus (E)	Rp (0.2)
Copper C17410 at 20C	138 GPa	620 MPa
Copper C17410 at 4K	148 GPa	740 MPa



Stress intensity at 4K



Stress intensity at 4K

Conclusions and outlook I

- Cavity prototype fabricated.
  - Tooling an teething problems ironed out
  - 5 more pre-series in fabrication (one full cryomodule)
  - Tuning plate, couplers in fabrication

- Coating development:
  - Study I-V curves as a function of sputter gas pressure, bias voltage.
  - Characterize RRR of samples.
  - Optimize geometry if necessary

- Surface treatment optimization:
  - Tests on samples and on dummy cavity successful
  - Waiting for first cavity treatment

- Samples characterization setup ready
  - Plus access to CERN facilities: SEM, XPS, etc.

Conclusions and outlook II

- First cavity coating expected during July/August 2009
  - Optimization work has to proceed fast
  - All tooling is ready (for clean room assembly, etc.) except for ultrapure water rinsing. This operation will be done by hand, series tooling delayed after first prototype.
  - RF test not available at CERN in the short term

- Goal: achieve nominal specifications by end 2009

Finally

Main contributors

- *Mechanical design:* Philippe Trilhe, Franck Thierry, Philippe Perret, Gilles Villiger, Delio Duarte Ramos, Luca Gentini, Ricardo De Morais Amaral
- *Mechanical fabrication:* Thierry Tardy, Christian Saint-Jal, Jean-Marie Geisser, Jean-Pierre Brachet, Pierre Moyret, Rene Claret, Ahmed Cherif, Dominique Pugnat.
- *Surface treatments:* Leonel Ferreira, Serge Forel, Marc Thiebert
- *Coating:* Giulia Lanza, Antonio Mongelluzzo, Jean Cave, Anna Gustafsson
- *Cryolab:* Tapio Niinikoski, Friedrich Haug, Sebastien Prunet, Laetitia Dufay-Chanat